

Session E :-

SPACE AND AVIATION

Lecture No. 12

Chairman: Prof. D. Abir,  
Fac. of Aeronaut. Eng.  
Technion Haifa and  
Israel Aircraft Industries.

FACILITY FORM 602

N71	22398	(THRU)
29		23
(PAGES)		(CODE)
TMX 67072		30
(NASA CR OR TMX OR AD NUMBER)		(CATEGORY)

FROM APOLLO 11 TO THE SPACE STATIONS OF THE FUTURE

H. Cohen  
Director Reliability, Quality & Safety -  
Apollo Project, National Aeronautics and  
Space Administration, Washington, D.C.

Annual Symposium

National Council for Civil Aviation

Tel-Aviv - Israel

October 8-9, 1969

The culmination of a decade of effort has come with the flight of Apollo 11. Man has left the earth, visited and explored another world a quarter of a million miles away, and returned safely. This will stand as the greatest and most far-reaching achievement of our time. History will refer to our generation as the one that ushered in the space age, and not only opened up vast reaches of space to man's machines, but made them accessible to man himself. A movement has been started which will not stop, and which will in the course of time extend man's domain throughout the solar system.

History teaches over and over that the long-range results of great human ventures are often, perhaps usually, of greater importance to human advancement than are the short-term values, even though the shorter-term values may have been the initial driving force. The ancients developed writing and the alphabet primarily to keep commercial records, but the long-term contribution to the development of literature, thought, science, religion, government - indeed the whole spectrum of human intellectual activity - far transcends the initial values. This paper will cover the next decade in space, but more importantly, where the next decade can and should lead us in the longer run. In this connection it is important to note that the achievements of the first decade in space are a direct result of proper concern with the longer-range implications of what we initially undertook in space. Russia's first Sputnik shocked America as a country and raised some basic questions as to whether we really were the pioneering people we had thought, and whether we actually had the technical pre-eminence that we assumed. The National Aeronautics and Space Act of 1958, which created NASA, although sparked by Sputnik and seeking to respond to the immediate challenge, went far beyond the immediate problem to our present long-term capabilities in and use of space. This hard-won capability now opens up to us a great variety of new opportunities in space for exploration, science, applications, and technology advancement.

The crucial question will be what to choose as America's future role in following through on the opening up of the solar system to man. We have established what may be characterized as an initial foothold in space. Man will go farther. In the decade to come, there lies before us the possibility of discovering extraterrestrial life, a discovery that would probably rank as the greatest scientific event of the century.

The next natural step for us to take in space will be for us to create permanent space stations in earth and lunar orbits with low-cost access by reusable chemical and nuclear rocket transportation systems, and to utilize these systems in assembling our capability to explore the planet Mars with men. The key to carrying out this step in an effective and efficient manner will be commonality - the use of a few major systems for a wide variety of missions; reusability - the use of the same system over a long period of time for a number of missions; and economy - the reduction in the number of "throw-away" elements in any mission, the reduction in the number of new developments required, the development of new program principles that capitalize on man's capabilities to operate, maintain and repair space facilities, and the commitment to simplification of space hardware.

Before we proceed to examine these next steps, let us take a look at the giant one we have just recently completed (S-1 thru S-26). Of great interest to the world are the results of our weeks of preliminary analysis of the 48 pounds of lunar material brought back by the Apollo 11 crew on July 25th. The scientists reported that the chemical composition was "unlike that of any known terrestrial rock".

Their findings, based on the surprisingly large amounts of such rare elements as Chromium, Titanium, Yttrium and Zirconium in the lunar samples, led several scientists to suggest that at least one of the three leading theories on the origin of the moon now appeared unsupportable.

It still may be that the moon came from somewhere else in space and was captured by earth's gravity, or that it and the earth were

formed at about the same time and out of the same matter.

But the notable differences in lunar and earth chemistry, the scientists said, seem to rule out the third hypothesis - that the moon is a fragment that ripped off the earth when the earth was young.

Of equal interest to the scientists was what they did not find.

The scientists did not detect any signs of such precious metals as gold, silver or platinum. They were also intrigued by the low incidence of elements with low melting points, such as lead, bismuth, sodium and potassium.

The scientists studying the rocks and dirt from the Sea of Tranquility confirmed earlier reports that some of the rocks are as much as 3.5 billion years old.

The scientists called this the "most exciting observation" thus far.

This raises the exciting possibility that future flights to the moon will find rocks dating back to the beginning of the solar system.

When astronauts visit the lunar highlands, whose surface features are believed to be even more ancient than the plains, they may collect rocks about 4.5 billion years old, the estimated age of the earth, moon and solar system.

The oldest known terrestrial rocks to have survived earth's erosive winds and water are 3.5 billion years old.

Many of the rocks are igneous, meaning that they were once in a molten state, either from volcanic eruptions or from the heat generated by meteorite impacts.

Impacts from meteorites or from flying debris from volcanic eruptions have had a major role in shaping the face of the moon. All the Apollo 11 rocks had glass-lined surface pits, which may be caused by showers of small particles.

Most of the rocks, though 2 billion to 3.5 billion years old, have been periodically tossed about and turned over. This was indicated by the presence of pitting all over the surface, not just on the upper side.

Erosion has occurred on the lunar surface - most rocks are rounded and fairly smooth. Such erosion might come from solar radiation or micrometeorite impacts.

Lunar dust and non-igneous rocks - breccia, or conglomerate rocks - contain large amounts of gases that apparently are the atomic particles that boil off the sun as the so-called solar wind and steadily bombard the moon's surface.

Chemical analyses of 23 lunar samples showed that all the rocks and dust were similar in composition, indicating that they were characteristic of a large region of the Sea of Tranquility.

No evidence has been found thus far of any organic material in the fragments to indicate any living processes on the moon. No people or laboratory animals exposed to the moon dirt have developed any reactions.

The samples of crystalline igneous rocks were found to contain as much as 12 percent titanium oxide. The richest titanium lodes on earth, in certain volcanic rocks, contain no more than 4.5 percent.

Ten times more chromium was discovered in the lunar rocks than is common in earth rocks.

Titanium and chromium, as well as yttrium and zirconium, have extremely high melting points, although sometimes in mixtures the point is reduced.

Consequently, the scientists said in their report that this "unique composition implies either the composition of the rock from which the liquid was derived differs significantly from that of the mantle of the earth, or that the mechanism by which the liquid was formed differs from analogous terrestrial processes".

It will be necessary to explore in depth many varieties of surface features of the moon about which we already have some information. For this reason, we are planning later flights using the Saturn V Launch Vehicle and the equipment which has been prepared for Apollo. Scientists will go to the moon -- geologists, mineralogists, geochemists, and geophysicists will be among the first.

We expect to permit the astronauts to increase their area of exploration by going on traverses as far as five kilometers from the landing point. Take the Marius Hills, for example, we would expect to land about a kilometer away, walk to and up the hill, taking samples up to and over the top and going down the other side.

Another region of particular interest is the Hyginus Rille region. By shooting appropriate samples, scientists should be able to determine the origin of the rilles running across the lunar surface.

Another possibility, of course, is that we might find valuable minerals. Some of the craters are obviously due to huge meteors striking the surface. Along the boundary between the parent material and the meteor we would expect to have a region that experienced very high pressure and very high temperature. It is the kind of area in which diamonds form, for example, and where other minerals of that kind might be expected to be found.

This is speculation you understand, but if it is proven true - the long range economic returns will be great.

Beginning with the first landing, the current lunar program consists of four flights to visit places typical of large areas of the moon. Two missions are to the lunar seas, the mare, and two to the highlands. For the second of the missions to the highlands, a landing will be tried close enough to a crater to get a first sample of the lunar material in depth. At the end of this phase of exploration, we will have early data on the broad composition of the lunar surface materials and may be able to determine whether there are important chemical differences between different sites. It is hoped the scientists will have established the relative geological ages of the mare and the highlands and perhaps have been able to lay a framework for the history of the moon.

Current plans include at least nine additional flights. These will be visits to unique sites for the purpose of examining the specific processes which have made the major differentiations in the lunar surface. In order to conduct these later missions, we will have to improve our landing accuracy and make some changes in the hardware. In addition, we will, of course, require greater stay time to cover the points of scientific interest at each site, and greater mobility to cover points of interest which are not located near each other. In order to reach places off the lunar equator, we will have to go into non-equatorial orbits. These more ambitious explorations will require modification to the command, service and lunar modules as well as improvements in the space suit and in the portable life support system. Finally, continuation of the geophysical investigation of the lunar interior will require a second generation of experiments. This second phase of lunar exploration is expected to be completed about the end of 1972.

Currently under study is the definition of a follow-on program -- a survey for a lunar base site. This study will be conducted while extended scientific exploration continues, while prospecting for resources goes on and while experimental base hardware and equipment is being tested.



Throughout history, we have explored by the same basic process. First, we have had to have the transportation necessary to take us to the new territory; we have made quick sorties into the new area, and we have explored sufficiently to decide where we will establish a base. We believe that the same process will probably go on on the moon. We will make a few landings, we will hopefully extend the stay-time on the moon to three days. The astronauts will have perhaps 36 hours of extravehicular activity, and in the process will have gathered information which may contribute eventually to the establishment of a lunar base. Such a base will probably be built up slowly, taking parts of necessary equipment to the moon on different visits and eventually, build up a base on the lunar surface which may in many respects resemble the bases in Antarctica.

We fully expect that we will find both material and information on the lunar surface which will be of sufficient importance to us to continue our activity there.

Besides serving as a subject of scientific exploration for its own secrets, the moon may be an important base for outward looking space science programs of the future.

Astronomy appears most likely to profit from lunar based investigation. Briefly, the moon may eventually support large optical telescopes, though the advantages of the moon for this use over earth synchronous orbits are not yet clear. On the other hand, there is strong evidence that the most ideal location for large radio telescopes will eventually be the far side of the moon. This may be the only place within our convenient reach where the earth, which will become increasingly noisy as a radio source, may be completely screened out. In addition, the lunar surface presents us with a very large stable base, with only  $1/6$  gravity, no wind disturbance and no atmosphere absorption at any wave length. All of these contribute to advantages for large radio telescope installations.

Another attractive possibility is to use stations on both the moon and earth as radio interferometer baseline for highly precise directional radio astronomy. In view of the rapid growth and importance of radio astronomy and the large sums now being invested in radio telescopes, far-side lunar operations within fifteen years should be considered very seriously.

There are also attractive possibilities for installing large X-ray and Gamma-ray telescopes on the moon and using the atmosphere-free lunar horizon as an occulting edge that rotates uniformly about the sky. These, unlike the radio telescopes, need not be on the far-side since earth noise is not a problem here.

The moon is certain to serve as a valuable permanent base for monitoring the environment of our solar system, especially particles and fields. Solar wind, solar storms, magnetic perturbations, meteorite in-fall, and cosmic rays will all be worthy of continuous monitoring from a lunar base. This will augment earth based observations by data taken at a significant distance and time away from the earth.

A third scientific and technological use of the moon might be for laser communications with spacecraft in cislunar space, and on planetary missions. The lack of atmosphere, of clouds or of ionosphere at a lunar terminal would give it obvious advantages over continuous laser communications channels that must penetrate the earth's atmosphere.

As our space exploration programs evolve, the moon may be used as a refueling and launching platform. Because of its low gravity, it requires twenty times less energy to escape from the moon than from the earth, hence, if rocket propellants can eventually be developed from lunar resources, there will be an advantage in using the moon as a supply and launch base for interplanetary operations.

Whatever develops in the way of utilizing the unique characteristics of the moon, either for earthly or space benefits, we will surely

require a base from which to work.

It is the considered opinion of many of our scientists as well as those primarily interested in space, that the establishment of a large and flexible space station is the second logical step in space exploration. Flexibility will be assured by constructing the station of special modules. Such a station in orbit, would, of course, significantly reduce the cost of individual space investigations, assuming an economical logistics system, which will be discussed later.

Before proceeding to the large, flexible space station, we will build an embryonic smaller version utilizing equipment developed in the Apollo program. This intermediate step will provide us with needed data on effects of long duration space flight on both men and systems, demonstrate that orbital scientific investigations can be efficiently carried out, including the operation of a manned solar observatory, and prove that operation of a space station is indeed feasible. This early space station is in the form of a three-man workshop which will orbit the earth during 1972 and is currently under development in the Apollo Applications Program.

It is desired to take advantage of the superb vantage point for viewing the earth provided by missions in earth orbit lasting months or years. The next step, therefore, is to provide the larger, more sophisticated, longer-life space station facility. Attached to such manned facilities will be instruments for observations of the earth, both for science and applications purposes.

Especially important will be the development, test and establishment of operating techniques for telescopes, multispectral cameras, infrared radiometers, radars, lasers, spectrometers and other instruments which will give new information to trained astronauts in earth orbit in atmospheric and earth science problems. Examples of such special observations are studies of atmospheric circulation, heat balance, air pollution, and meteorologic and oceanographic dynamics. These observations will

permit man to discover, by seeing and carrying out sophisticated measurements upon these preprogrammed observations of automated instruments. We would expect that these manned observations will provide the analysis and direction that will permit a total earth sensing program, both automated and manned, to take advantage of the unexpected knowledge and insights that will result in rapid and effective use of the earth sensing information.

Turning now to other disciplines, we expect that manned space laboratories in earth orbit will be the natural means of studying the effects of the space environment on man, animals and plants. While the initial emphasis must be to qualify man himself for space flight, studies on the effects of zero gravity, lack of diurnal cycles and radiation effects are certain to lead to useful increased knowledge of living systems on earth. A manned space station will afford, for the first time, the possibility of carrying out studies on man in a reasonable volume, with good medical facilities, for long duration and with many crew men. The availability of astronauts to conduct tests and observations on plants and animals in space, to use microscopes, and to return specimens to earth, will make enormous progress possible in this field.

In another module of a manned space station, we expect eventually to see a high energy cosmic ray and high energy physics laboratory. Studying the cosmic rays for their own properties will tell us about the nature and origin of the universe, observations that cannot be carried out on earth or even in balloons. Letting the rare but extremely high energy particles from the cosmic rays interact with chosen forms of matter such as hydrogen, the physicist may test theories on the nature and properties of nuclei.

It is possible, due to the very high energy particles available, that such a high energy physics laboratory, at a modest incremental cost to the space station, can accomplish studies impossible with the largest nuclear accelerators we will have built by that time

For the most efficient exploitation of the space environment, a space station accommodating a dozen or more scientists and technicians will be required. The station will be designed for a minimum of ten years of operational life, its cost being amortized by extended use. Since the station will be a modular installation, modules can be changed, thereby preventing obsolescence and providing research flexibility. Three kinds of modules, utility, living and experiment, will form the basic station. To these can be added whatever facilities are appropriate at later dates. The installation of such a platform in earth orbit will give us a research, development and operations facility for accomplishing the increasingly important space goals we envisage for the latter half of the next decade.

Knowledge of the earth has already been notably enriched by examinations from space. Different objects and conditions on earth give off distinctive amounts of heat or light, reflecting a different "signature" to cameras and spectrometers. The amount of heat or light reflected not only distinguishes a crop, but can also be interpreted to ascertain its degree of maturity and its health. With a certain number of earth sensing satellites in polar orbit, we could know well in advance approximate size of the world's forthcoming rice, wheat, corn and sugar crops. With this knowledge, properly applied, it may be possible to improve the distribution of the world's food. By rapidly pinpointing crop disease, remedial or preventive action would greatly decrease annual losses from crop blight. Thus, the management of food for an exploding population becomes potentially possible through the uses of space.

Space photographs offer geologists a valuable business tool, but, more importantly, promise to unlock new mineral deposits quickly enough to supplant those which are being so rapidly exhausted by our industrial acceleration.

Waters cover five-eighths of the earth's surface, and their riches are going to have to be mined to feed the increasing appetites of the world's growing population.

Much is being learned about the ocean floor from satellite observation. From 100 to 200 miles in space the bottom of the ocean is often as vividly clear as a road map. Water temperatures vary as currents move through quiet waters. These thermal differences are discernible from space on infrared film. Underwater geological structure is also apparent from space, and maps of the ocean floor, so important to thorough exploration of the seas, will be improved by space photographs. The application of space-gained knowledge should speed our oceanographic accomplishments.

Even with this broad brush treatment of the subject, I think it is evident that there is a great deal of valuable work which should be done in earth orbit.

NOT REPRODUCIBLE

The uses of space have been limited in concept and extent by the high cost of putting a payload into orbit, and the inaccessibility of objects after they have been launched. Today we have in sight the technology necessary for reusable space vehicles. This knowledge, together with awareness of the logistic requirements of continuing space activity, leads to the conclusion that the next major thrust in space should be the development of an economical space vehicle for shuttling between earth and the installations, such as an orbiting station, which will be operating in space.

Ideally, the "space shuttle" would be able to operate in a mode similar to that of large commercial air transports and be compatible with the environment of major airports, taking off vertically from a small pad, dispatched by crews similar in size to those required for intercontinental jets, and upon its return from orbit, reentering the atmosphere and gliding to a horizontal runway landing.

Interestingly enough, the basic design for an economical "space shuttle" could also be the progenitor of an aircraft for terrestrial point-to-point transport. No place on earth would be more than one hour from any other.

Over the past several years, studies have progressed to the point where several promising concepts for an economical, reusable space vehicle already exist.

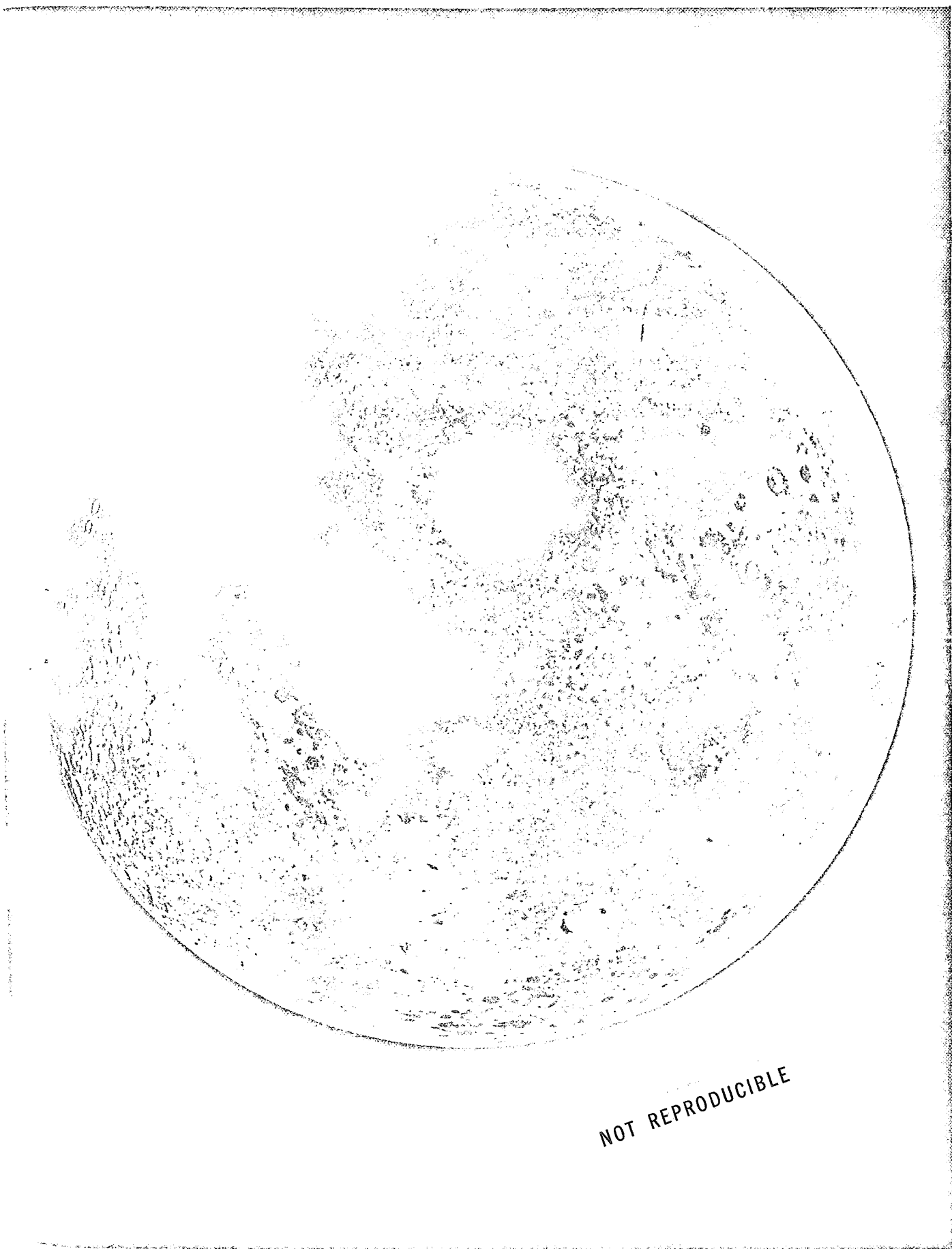
However, the germination period of new designs is from 7 to 15 years. Jet power, available in 1946, came into commercial use on the Boeing 707 in 1958. Driving against traditional time lags, the Saturn V system has been developed and used within 7 years of its conception.

It is reasonable to conclude then, that a "space shuttle" development program, initiated now, could be brought to fruition before the end of the 1970's.

Unfortunately, a critical need for such a transportation system will exist before then. We already know that crews and materials will need to be shuttled between earth and laboratories in space. Men and materials will be flown back and forth to the space stations which are scheduled to begin solar investigations in 1972. Communications, navigation, and earth-sensing satellites will probably require maintenance, or refit. In its role as a global transport, the "space shuttle" could go to work tomorrow.

The "space shuttle" is the key to our efficient utilization of the capability we now have and to the application of the knowledge we have already gained. It will be the bridge which will carry space-gained knowledge across the gap between the public and private sectors for profitable earth applications.

In conclusion, we stand today with a tested and efficient system for the orderly exploration of the unknown, with the people, the motivation, the knowledge, the facilities, and the equipment to attain the first place in space and in all related aspects of technology.



NOT REPRODUCIBLE

FIGURE 1



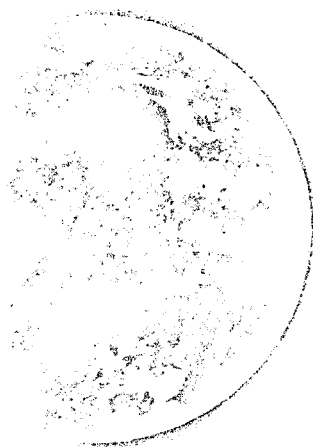


FIGURE 2

NOT REPRODUCIBLE

FIGURE 3



FIGURE 4

NOT REPRODUCIBLE

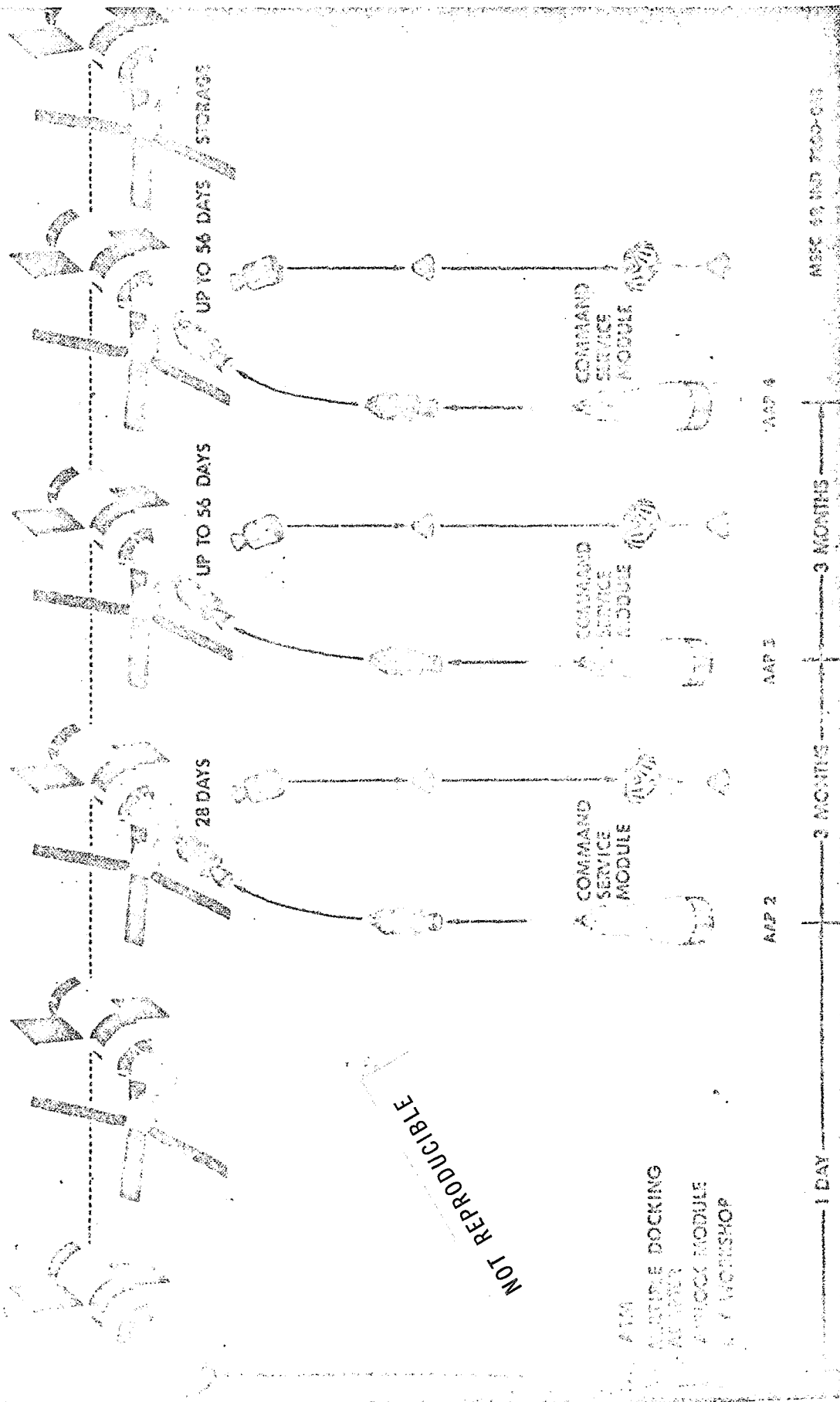
FIGURE 5



AVAP (QUESTER) CONTEH (NIO)  
SYATURN (WORKS) IO.

FIGURE 6

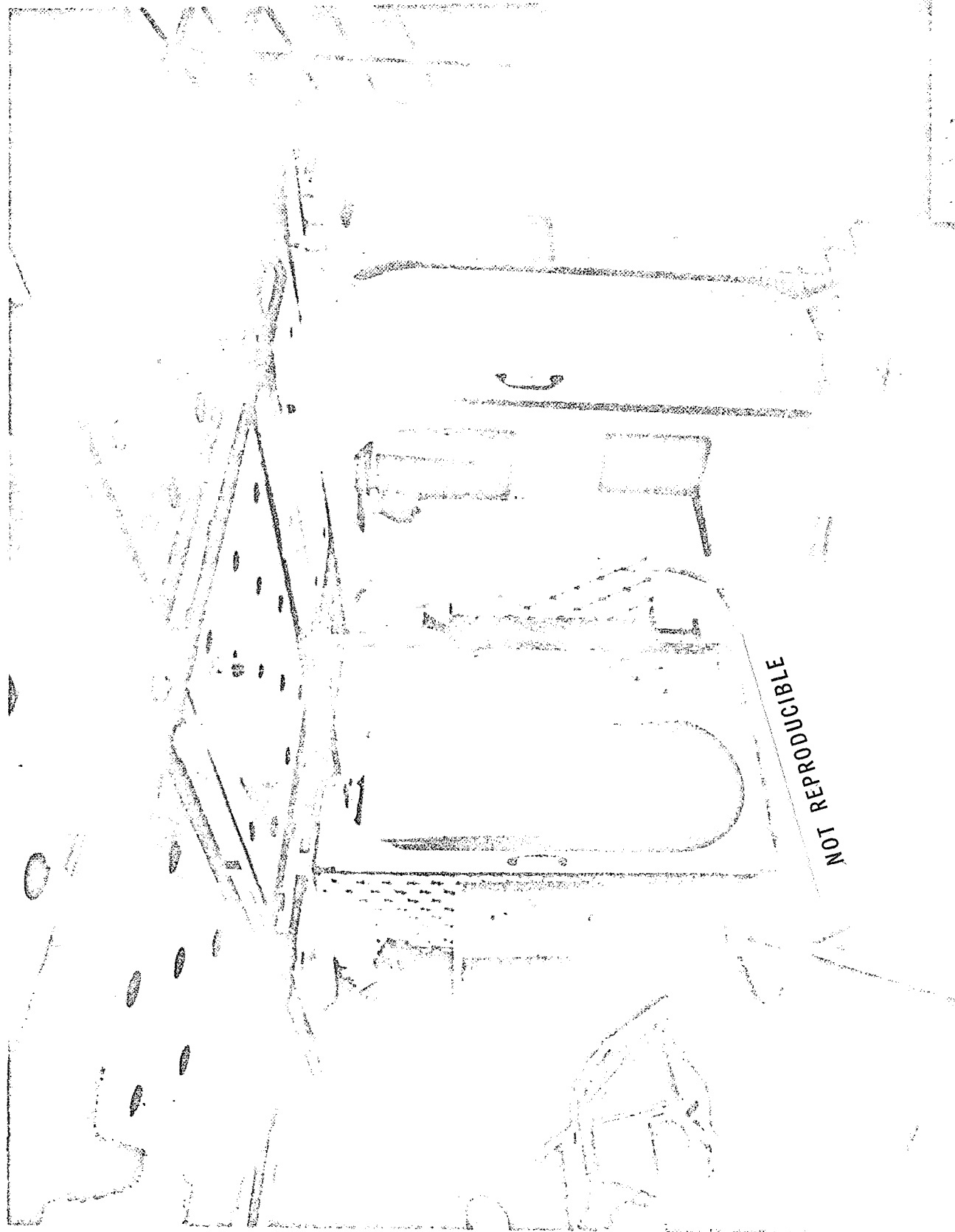
# SATURN WORKSHOP ACTIVATION AND OPERATION



NOT REPRODUCIBLE

FIGURE 7

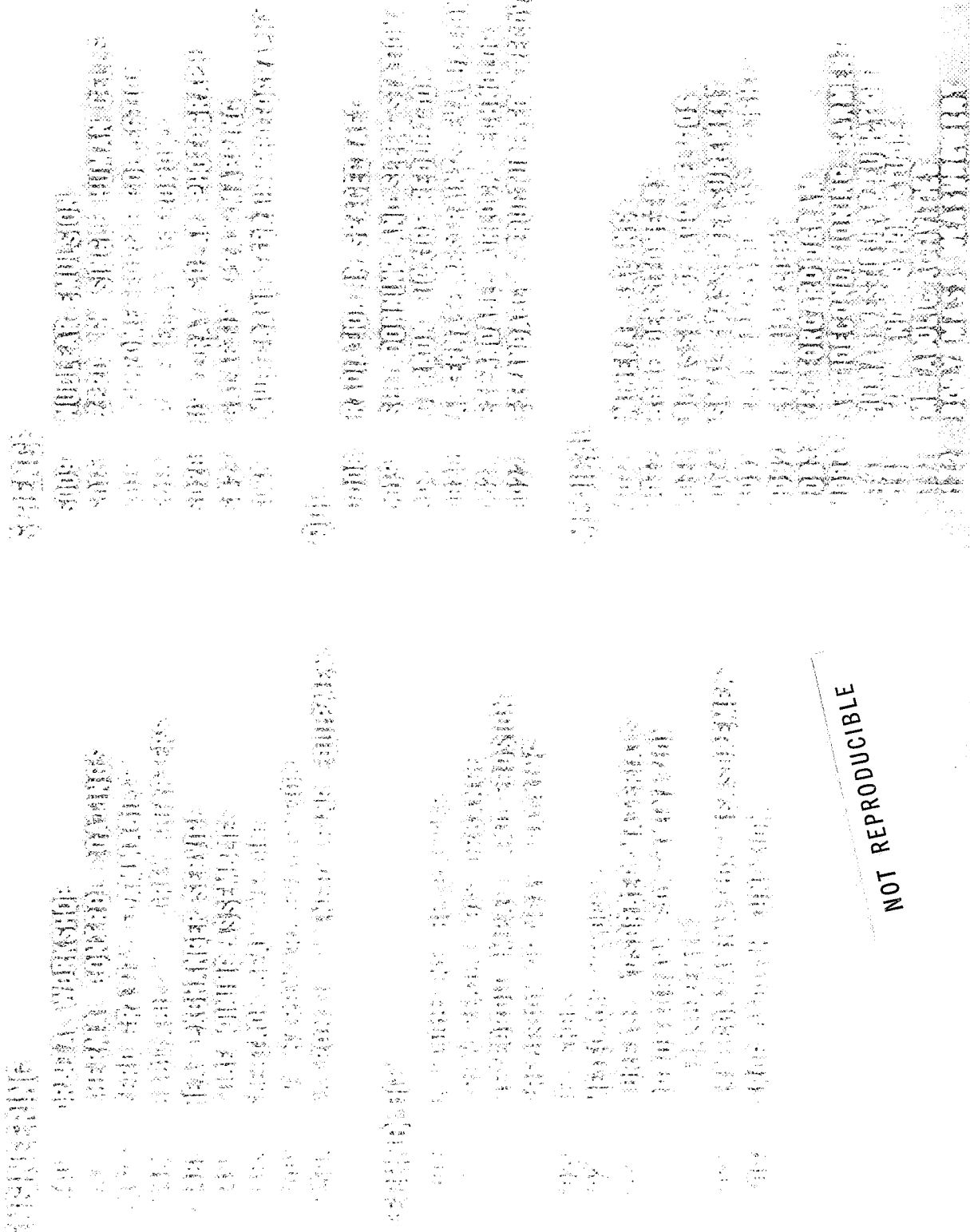
EXPERIMENT AREA



NOT REPRODUCIBLE

FIGURE 8

EXPERIMENTAL DATA



NOT REPRODUCIBLE

FIGURE 9



1975 COMMUNICATIONS / ARTIFICIAL "C" EXPERIMENT

COMMUNICATION

12

0100

NOT REPRODUCIBLE

NASA HQ-MT69-5503  
5-21-69

FIGURE 10

# PLANNED EARTH ORBITAL SPACE STATION

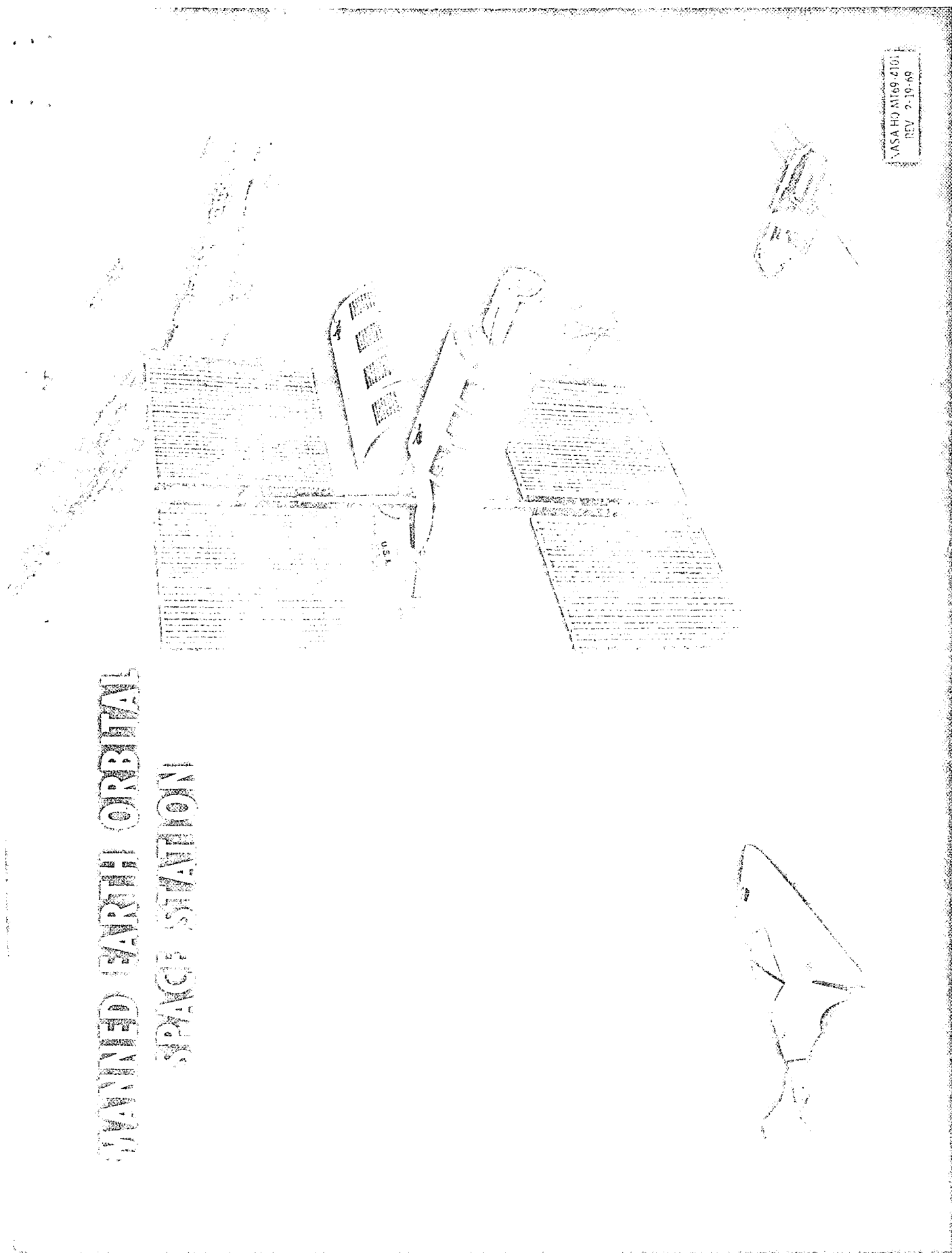
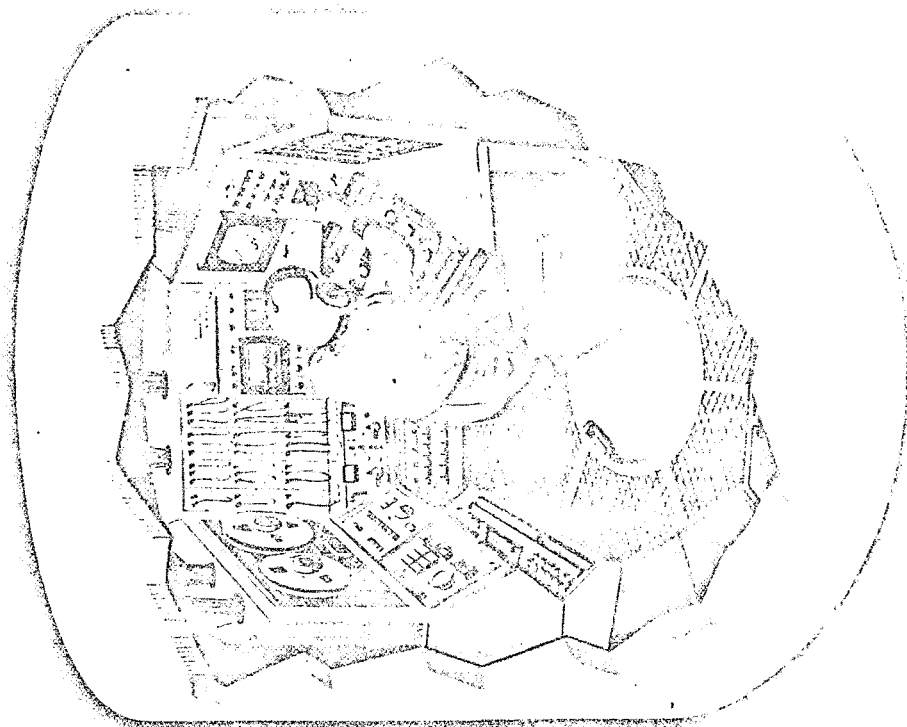


FIGURE 11

AND COASTAL RAY TROUBLE



NOT REPRODUCIBLE

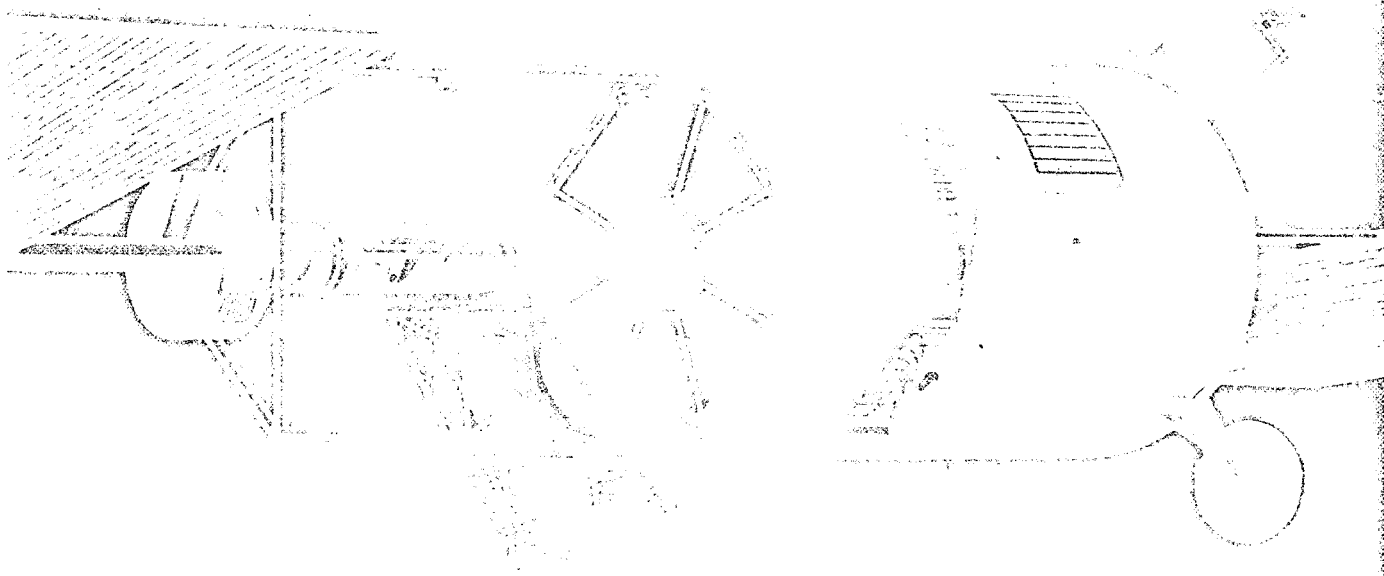


FIGURE 12

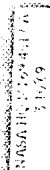


FIGURE 13

# PERSONNEL SHUTTLE



NOT REPRODUCIBLE

NASA HQ 2.1169-5762

7-2-69

FIGURE 14